

Final Report

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Study of Micrometeroid Orbital Debris

by

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INTRODUCTION

The measurement of high velocity impact dynamics in ground based ballistic gun facilities provides a useful and inexpensive methodology for simulating space meteoroid impact phenomena. Major thrusts are underway to measure the effects of impact damage at ballistic velocities on space related structural shells, in order to better understand the long term safety characteristics of materials in space, as well as to evaluate the materials currently available for platforms such as the Space Station.

The results of the high impact damages can be measured in a number of different ways in order to evaluate the effects of high velocity impact on structures. The hyperbolic velocity of micrometeoroids occur in the velocity range 15 - 20 km/sec, randomly distributed in all directions. On the other hand, space debris occupy circular orbits in the range 7 - 10 km/sec. Relative velocities of these particles with a space platform would then be in the range 8 - 20 km/sec for meteoroids and 3 - 12 km/sec for space debris.

Damage assessment studies have shown that impacts above the ballistic limit provide a number of measurable parameters, such as impact flash, penetration depth, spall/fracturing and shear cone. Impacts below the ballistic limit provide information from buckling, mushrooming of the impactor, and embedding. Resulting differences in the target also occur depending upon differences in geometry of the projectile, and relative values of hardness and density between the projectile and the target. Experimental data obtained during the impact experiments are already recorded and consist of kinetic energy data and flash x-ray images. These items are already deposited with other appropriate information stored at MSFC. The mechanical parameters obtained after the impact experiments are the major goal of this report.

Projectile velocities of 3 to 7 km/sec are achievable in the light gas gun at MSFC for particle diameters in the range between 3 to 8 mm. The types of damage observed with a variety of space station bumper and shield materials includes the following:

- Craters - A divot located on the front panel causing a dimple on the back side.
- Dimples - An outward indentation in the panel on the backside.
- Detached spall - Material missing from the backside of the panel.
- Attached spall - Material deposited on the backside of the panel.
- Fine spray - Small craters that do not create dimples.
- Petals - Material that is bent toward the projectile exit.
- Damage diameter - The area affected by the projectile.
- Number of holes - Total number of penetration holes.
- Deformation - A measurement of the deflection of the plate after impact.
- Wagon wheel - A fine spray that appears to look like a starburst.

RESULTS - see attached sheets

Aluminum Projectile

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
1316	0.187" Al-1100	Bumper							
	0 deg target angle	Wall							
		Witness	2024 Al	0.020"	No				3 craters/dimples, deepest crater 0.03"
1320	0.187" Al-1100	Bumper			Yes	0.336"			
	0 deg target angle	Witness			No				8 lg. craters, several sm. craters, dam area 1.75"x2.4", dimples
1321	0.187" Al-1100	Shield	6061-T6 Al	0.040"	Yes	0.406" & 0.096"			
	0 deg target angle	Bumper	Matrix	0.063"					Missing
		Wall	2219-T87 Al	0.125"	Yes	0.332"			8 lg. craters/dimples, fine spray, dam area 5.75x7, detached spall
		Witness	2024 Al	0.020"	Yes	Pin Hole	3	0.19", 0.125", 0.04"	6 craters, 4 dimples
1324	0.25" Al-1100	Bumper	Matrix #PER-2908		Yes	0.69"			
	0 deg target angle	Wall	2219-T87 Al	0.125"	No				Fine spray, many craters/dimples, lg crater: 16" dia x .089 deep
1326	0.187" Al-1100	Bumper	Matrix #PER-2486		Yes	0.458"			Fine spray, no dimples
		Wall	2219-T87 Al	0.125"	No				Approx. 14 craters/dimples, dam area 6.5x6.0, fine spray
1327	0.25" Al-1100	Bumper	Matrix #PR-1730		Yes	0.432"			
	0 deg target angle	Wall	2219-T87 Al	0.125"	No				Approx. 20 craters/dimples, dam area 7.25x7, 2 detached spalls
1328	0.187" Al-1100	Bumper	Matrix #D1813		Yes	0.54" x 0.64"			Material peeled back around hole
	45 deg target angle	Wall	2219-T87 Al	0.125"	No				Fine spray, lg. crater .17"x.22"x.06" deep, damage area 6"x7.5"
1329	0.187" Al-1100	Bumper	Matrix #D1813		Yes	0.55" x 0.57"			Material peeled back around hole, craters, no dimples
	45 deg target angle	Wall	2219-T87 Al	0.125"	Yes	0.125"			Several craters/dimples, largest .185x.074 deep, dam area 7x7.5
		Witness #1	2024 Al	0.020"	No				2 craters, largest 0.07"x0.13"x0.02" deep
1331	0.187" Al-1100	Bumper	Matrix #PER-2505		Yes	0.418" x 0.513"			1 detached spall on backside
	45 deg target angle	Wall	2219-T87 Al	0.125"	No				Many craters/dimples, largest .25x.13 deep, dam area 7.5 dia
1332	0.187" Al-1100	Bumper	6061-T6 Al	0.080"	Yes	0.388"			
	0 deg target angle	Wall	2219-T87 Al	0.125"					
		Witness #1	2024 Al	0.020"	Yes		3	0.118", 0.107", 0.122"	6 craters, 1 hole with 3 petals
1336	0.187" Al-1100	Witness #1	2024 Al	0.020"	No				Approx. 8 craters with dimples, Damage area: 0.75" x 1.25"
	0 deg target angle								
1338	0.250" Al-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.55" Dia.			
	0 deg. target angle	Wall	2219-T87 Al	0.125"	Yes	0.06" Dia.			Many craters, wagon wheel, dam area 10.5" dia, detached spalls
		Witness	2024 Al	0.020"	No				Numerous craters, Dam. Area 1.75" x 2.0"
1339	0.250" Al-1100	Wall	2219-T87 Al	0.125"	Yes	Max 1.4" x 1.6"			Numerous holes, wagon wheel, detached spalls
1340	0.250" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.45" x 0.42"			
	0 deg. target angle	Wall	2219-T87 Al	0.125"	Yes	Max: 0.17x0.08"			5 measurable holes 0.08, 0.09, .16x0.06, .06", detached spalls
1341	0.250" Al-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.59" dia.			
	0 deg. target angle	Wall	2219-T87 Al	0.125"	Yes	Max: 0.14x0.16"			3 holes, 5 detached spalls, wagon wheel, dam area 12" x 10.5"
1342	0.250" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.52" x 0.46"			
	0 deg. target angle	Wall	2219-T87 Al	0.125"	No				3 detached spalls, 6 dimples, dam area 9.5" x 11", fine spray
		Witness	2024 Al	0.020"	No				~ 8 craters, small crack, damage area 1.5" x 2.0"
1343	0.250" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.44" dia.			
	0 deg. target angle	Wall	2219-T87 Al	0.125"	Yes	Max: 1.18 x 0.84"			11 holes, detached spalls, dam area 10"x12"
		Witness #1	2024 Al	0.020"	Yes		7	1.23, 1.09, 0.97, 0.44, 1.19, 1.32, 0.8"	
		Witness #2	2024 Al	0.020"	Yes		3	0.58", 0.65", 0.22"	3 holes
1345	0.250" Al-1100	Wall	2219-T87 Al	0.125"	Yes	2.28"x1.09"			Detached spalls, wagon wheel, 9 dimples, dam area 8.5 x 8.0"
1346	0.250" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.50" dia.			2nd hole .22x0.17", 3rd hole has 4 petals, pin holes, fine spray

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
1348	0.250" AI-1100	Wall	2219-T87 Al	0.125"	Yes	0.76" dia.			1 crater w/ dimple, fine spray
1349	0.250" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.51" dia.			
	0 deg. target angle	Wall	2219-T87 Al	0.125"	Yes		3	0.80", 0.77", 0.47"	Numerous small holes, lg. detached spall 1.8x1.63", fine spray
		Witness #1	2024 Al	0.020"	Yes	Overall 1.93x1.15			Small crack to the left of holes
		Witness #2	2024 Al	0.020"	No				13 large craters
1350	0.250" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.50" dia.			
	0 deg. target angle	Stuffing	MLI		Yes	See photo			
		Wall	2219-T87 Al	0.125"	Yes	Max.: 32"x0.22"			
1353	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.59" dia.			
		Shield #2	6061-T6 Al	0.050"	Yes	3.4" x 4.6"			Damage area radiates the whole pattern, wagon wheel
		Stuffing	MLI	20 layers		See photo			
		Wall	2219-T87 Al	0.125"	No				No perforation, damage area ~5"
1357	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64" & 0.37"			
	0 deg. target angle	Stuffing		2 layers	Yes				
		Wall	2219-T87 Al	0.125"	Yes	Cracks/Pin holes			2 cracks 6.875" & 1.03", damage area ~ 6.875" x 3.5"
1358	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64"			Secondary hole 0.38"
	0 deg. target angle	Stuffing		2 layers		See photo			
		Wall	2219-T87 Al	0.125"	No				Plate deflected ~ 0.60" damage area 4" dia
1359	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64" dia.			
		Wall	2219-T87 Al	0.125"	No				~ 0.5" deflection of plate, damage area 5.5" x 5.0"
1360	0.250" AI-1100	Stuffing	MLI	20 layer	Yes	See photo			
	0 deg. target angle	Shield #1	6061-T6 Al	0.050"	Yes	0.52" dia.			
		Wall	2219-T87 Al	0.125"	Yes	0.14x0.15"			2nd hole .17x.07, 3rd .12x.05, 4th .07" d, dam area 8.5x7.875"
		Witness #1	2024 Al	0.020"	No				9 craters with dimples, dam area 2.875" x 2.0"
1362	0.375" AI-1100	Stuffing	MLI	20 layer	Yes	See photo			
	0 deg. target angle	Shield #1	6061-T6 Al	0.050"	Yes	.070" dia.			
		Wall	2219-T87 Al	0.125"	Yes	3.0" x 2.2"			Wagon wheel, detached material on rear, dam area 8.5" x 11"
		Witness #1	2024 Al	0.020"	Yes		9		Damage area 4.375" x 4.75"
		Witness #2	2024 Al	0.020"	Yes		9		Damage area 4.25" x 3.75"
		Witness #3	2024 Al	0.020"	Yes		7		Damage area 2.75" x 3.00"
1363	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64"			2nd hole 0.44 x 0.36", 3rd 0.22" x 0.17"
	0 deg. target angle	Honeycomb			Yes	See photo			
1364	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64" dia.			
	0 deg. target angle	Shield #2	Lanxide Comp.	0.123"	Yes	2.06 x 1.95"			Wagon wheel
		Wall	2219-T87 Al	0.125"	Yes		3	4.3" .3.92", 2.17"	Damage area 5.25 x 6.5"
		Witness #1	2024 Al	0.020"	No				~ 6 craters w/ dimples, damage area 4.5" x 2.25"
1366	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.64" dia.			
	0 deg. target angle	Shield #2	Lanxide Comp.	0.061"	Yes	2.34" x 2.40"			Secondary hole 0.39" x 0.34"
		Wall	2219-T87 Al	0.125"	Yes		6	2.13, 1.78, 1.48, 2.1.45, 1.47	Wagon wheel
		Witness #1	2024 Al	0.020"	Yes		4	1.66, 1.96, 1.02, 1.52, 1.50"	Damage area 4.75" x 5.0"
		Witness #2	2024 Al	0.020"	Yes	1.65" x 0.56"	5		Damage area 4.5"
1367	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.63" dia.			Elongated hole, damage area 2.0" x 2.0"
	0 deg. target angle	Shield #2	Lanxide Comp.	0.061"	Yes	1.64" dia.			Material deposited on front and rear of panel
		Shield #3	Lanxide Comp.	0.061"	Yes	~2.0" dia.	7	2.63, 2.43, 62, 1.24, 1.85, 2.14, 2.1	Plate broke in 3 pcs.
		Wall	2219-T87 Al	0.125"	No				Plate deflected ~ 0.57", damage area 4.0" dia., fine spray

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
1368	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.63" dia.			
	0 deg. target angle	Shield #2	Lanxide Comp.	0.031"	Yes	1.80" dia.	3	0.96, 1.21, 1.85"	Damage area 4" dia.
		Shield #3	Lanxide Comp.	0.031"	Yes	5.5" x 4.0"	4	0.37, 0.44, 2.5, 1.48"	
		Wall	2219-T87 Al	0.125"	No				Plate deflected ~ 0.60", damage area 5.0" dia.
1380	0.375" Al-1100	Shield #1		0.050"	Yes	0.46" Dia.			Numerous holes, 3 large holes, 0.46" d, 0.19x0.49", 0.29x0.26"
	0 deg. target angle	Shield #2		0.032"	Yes		6	.96, .37, .56, 0.65, 0.71, 1.05	Numerous small holes, fine spray
		Shield #3		0.032"	Yes		6	.72, 1.24, 1.33, 1.5, 1.74, 1.66	
		Stuffing			Yes	See photo			
		Wall		0.125"	Yes	.36x.19, .15x0.17			10 craters with dimples, fine spray
1381	0.375" Al-1100	Shield #1		0.050"	Yes	0.47" x 0.42"			
	0 deg target angle	Shield #2		0.032"	Yes		7	2.19, 1.75, 2.06, 1.95, 1.52, 1.97, 2.02	
		Wall		0.125"	Yes	Max. 0.61x0.44			Numerous craters, large detached spall
1383	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	Largest 0.52" dia			3 holes, largest hole measured
	0 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	Largest 0.84" dia			Wagon wheel, largest hole measured
		Blanket	MLI Blanket	20 layer	Yes	See photo			
		Wall	2219-T87 Al	0.125"	Yes	0.25" x 0.2", 0.14"			3 holes, 9 craters with dimples, fine spray
1385	0.25" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.47" x 0.41"			
	0 deg. target angle	Wall	2219-T87 Al	0.187"	No				~ 6 craters w/ dimples, wagon wheel, dam area 10"x11.5"
1386	0.250" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.47" x 0.44"			
	0 deg. target angle	Wall	2219-T87 Al	0.187"	Yes	Largest .67x.24"			4 holes, detached spalls, many craters, 6 craters w/ dimples
1403	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.62" x 0.56"			Secondary holes 0.28 x 0.21", 0.17 x 0.2", & 0.11" dia
	0 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes	Max. 2.24x1.75"	7	.8, .5, 1.07, .68, .68, .47, .42	Damage area 3.25" x 2.75"
		Shield #2	6061-T6 Al	0.063"	Yes	1.27" x 1.31"			~25 craters w/ dimp., fine spray, dam area 5" x 5.5"
		Wall	2219-T87 Al	0.125"	Yes	Pin Hole			2 cracks .32 and 0.11" long, dimp, fine spray dam area 2.75x3
1404	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.57" dia.			Secondary holes 0.19" x 0.15", 0.13" x 0.11", 0.21" x 0.14"
	0 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes	1.60" x 1.38"			Numerous craters w/ dimp., wagon wheel, dam area 4.25x6.75"
		Shield #2	6061-T6 Al	0.032"	Yes	3.53" x 3.42"			Damage area 4.75" x 4.25"
		Wall	2219-T87 Al	0.125"	Yes	0.62" x 0.48"			4 petals, petal lengths 1.34, 0.73, 1.19, 1.0, dam area 3.5" dia
1405	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.63" dia			
	0 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes	3.20" x 3.0"			Numerous holes, craters, dimples, and det. spalls, wagon wheel
		Wall	2219-T87 Al	0.125"	No				Fine spray, plate deflection ~0.20", damage area ~9.5" dia.
1406	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.60" dia.			Secondary hole 0.18" dia.
	0 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	3.20" x 3.42"			Numerous holes, craters, dimples, and detached spalls, ~3 petal
		Wall	2219-T87 Al	0.125"	No				Fine spray, plate deflection ~0.37", damage area 9.5 x 10"
1407	0.375" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.63" x 0.84"			
	45 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	Largest 1.2 x 0.8"			Numerous holes, craters, dimples, and detached spalls
		Wall	2219-T87 Al	0.125"	Yes	0.14" x 0.28"			2 holes .13 x .11", ~25 dimples, fine spray, dam area 9 x 12"
1408	0.375" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.67" x 0.95"			
	45 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes	0.79" x 1.25"			Holes, craters, and dimples throughout panel, detached spall
		Wall	2219-T87 Al	0.125"	Yes	0.15" dia.			~ 25 dimples, fine spray
1410	0.375" Al-1100	Shield #1	6061-T6 Al	0.080"	Yes	1.0" dia.			Edge of hole bent ~0.21" inward (toward projectile entrance)
	0 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	1.22" x 1.12"			Edge of hole bent ~0.23" outward (away from proj. entrance)
		Shield #3	2024 Al	0.020"	Yes	1.85" x 1.60"			Plate has curled petals around the hole, 16 petals
		Wall	2219-T87 Al	0.125"	Yes	2.43" x 1.95"			5 cracks on rear, fine spray, dam. area 8.75" x 9.5"
		Witness #1	2024 Al	0.020"	Yes	2.33" x 1.75"			Damage area 4.25" x 4.50"

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
		Witness #2	2024 Al	0.020"	Yes	1.98" x 1.02"			Damage area 3.0" x 2.5"
		Witness #3	2024 Al	0.020"	Yes	1.85" x 0.78"			Damage area 1.75" x 1.0"
1411	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.89" dia.			Edge of hole bent outward ~ 0.11"
	0 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes	0.95 & .18 x .14"			Edge of holes bent outward ~ 0.15"
		Wall	2219-T87 Al	0.125"	Yes	Max 3.11" x 2.5"			~ 30 dimples, fine spray
		Witness #1	2024 Al	0.020"	Yes		7	1.6,1.18,1.38,1.18,76,1.14,0.75"	
		Witness #2	2024 Al	0.020"	Yes		5		Damage area 5.0" dia.
		Witness #3	2024 Al	0.020"	Yes		5		Damage area 4.5" x 3.75"
1412	0.187" AI-1100	Shield #1	6061-T6 Al	0.032"	Yes	0.38" x 0.33"			
	0 deg. target angle	Shield #2	6061-T6 Al	0.032"	Yes		4	0.92",1.19",1.47",1.0"	Many small holes, slight defl. of plate, dam area 8.75 x 8.5"
		Wall	6061-T6 Al	0.063"	No				Dim. on rear, fine spray, slight defl. of plate, dam area 4.5" dia
1413	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	Largest 1.01x1.18			Other holes .52x.45", 0.43x0.34", small petals formed on rear
	45 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes	Largest 1.59x1.76			Other holes .39x.5", .41x.3", lg hole has 7 petals, craters/ dim.
		Wall	2219-T87 Al	0.125"	Yes	Largest .93x.51"			8 holes total, craters w/ dim., fine spray, dam area 9.25x8.5"
1414	0.375" AI-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.75" x 0.96"			
	45 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes	Largest 1.04x.83"			Numerous holes radiate outward, dam area 12" x 9.5"
		Shield #3	6061-T6 Al	0.063"	Yes		8	1.79,1.67,72,45,,78,94,1.18,,3	Fine spray, damage area 7.0" x 9.25"
		Wall	6061-T6 Al	0.063"	No	0.07" x 0.03"			Plate deflected ~0.25", dam area 4"x4.5", crack on rear 0.165"
1415	0.187" AI-1100	Shield #1	6061-T6 Al	0.032"	Yes	Largest .33x.43"			Other holes 0.24x0.18", 0.17x0.12", 0.13x0.08"
	45 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes	Largest .36x.33"			Numerous holes, craters & dimples, fine spray, dam area 9.5x9"
		Wall	6061-T6 Al	0.063"	Yes	Largest .14x.25"			Numerous holes, ~30 dimples, fine spray, dam area 6.5x9.0"
1419	0.375" AI-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.97" x 0.68"			Second hole 0.51" x 0.33"
	45 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	0.89" x 0.40"			Holes, craters & dimples radiating throughout plate, det. spalls
		Wall	6061-T6 Al	0.125"	Yes	0.15" x 0.17"			~ 30 craters with dimples, fine spray
1420	0.375" AI-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.71,0.16",0.11"	0		
	0 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes		8	1.23,0.16,0.87,0.40,0.57,0.86,1.04,1.59	
		Shield #3	6061-T6 Al	0.063"	Yes		7	1.65,1.54,2.16,2.23,2.5,2.41,2.46	
		Wall	6061-T6 Al	0.063"	No		0		Plate bent away from projectile impact, dam area 4.5"x5.68"
1425	0.375" AI-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.77" x 0.71"	0		Smaller hole meas. 2,.17,.12,.16,.07", craters, detached spall
	0 deg. target angle	Shield #2	6061-T6 Al	0.032"	Yes		8	0.9,0.89,0.43,0.68,0.56,0.62,0.52,0.88	
		Stuffing	Kevlar/MLI	10 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	No				Slight deflection of plate, fine spray, dam area 4.6 x 4.25"
1426	0.375" AI-1100	Shield #2	6061-T6 Al	0.063"	Yes	0.76" x 1.1"			Numerous holes, craters and detached spalls
	45 deg target angle	Wall	2219-T86 Al	0.125"	Yes				2 small pin holes, numerous craters
1427	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.89" x 0.69"			10 small holes, numerous craters
	45 deg target angle	Shield #2	6061-T6 Al	0.063"	Yes		8	0.74,27,39,45,24,25,16,.48,.53	
		Wall	2219-T86 Al	0.125"	Yes	0.07 x 0.08"			Several craters, dam area 5.18" dia.
1429	0.375" AI-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.75" x 0.95"			Small hole 0.02" dia.
	45 deg target angle	Stuffing	Kevlar	6 layers	Yes		6	1.08,1.25,1.37,1.27,1.76,1.67	
		Shield #2	6061-T6 Al	0.063"					
		Wall	6061-T6 Al	0.063"	No				~ 16 craters w/ dimples, slight defl. of plate, dam area 3.5 x 3.8"
1430	0.375" AI-1100	Shield #1		0.080"	Yes	0.74" x 0.91"			Fine spray
	45 deg. target angle	Stuffing	Kevlar	8 layers	Yes		7	3.18,3.94,3.75,3.72,2.77,5.11,5.16	
		Shield #2		0.032"	Yes	See photo			
		Wall	6061-T6 Al	0.080"	Yes	0.05"			Numerous craters w/ dimples, fine spray, dam area 4" x 5.45"

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
1431	0.375" AI-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.74" x 0.92"			Fine spray on front and rear of panel
	45 deg. target angle	Shield #2	6061-T6 Al	0.032"	Yes	See photo	10	.66,.58,.4,.61,.64,.57,.74,.48,.27,.42	
		Stuffing	Kevlar/MLJ	10 layers					
1432	0.375" AI-1100	Wall	2219-T86 Al	0.125"	No				8 craters w/ dimples, fine spray, dam area 3.55x5.07"
	0 deg. target angle	Shield #1	6061-T6	0.032"	Yes				4 largest holes 0.52" 0.34x0.29", 0.33x0.26", 0.14"
1433	0.375" AI-1100	Shield #1	6061-T6	0.050"	Yes	Largest 0.89 x 0.63			Smaller holes 0.51x0.38", 0.17x0.11", numerous craters/spalls
	45 deg. target angle	Shield #2	6061-T6	0.032"	Yes		7	1.12,.57,.47,.43,.5,.54,.85	
		Stuffing	Kevlar	8 layers	Yes	See photo			
		Shield #3	6061-T6	0.032"	Yes		8	3.54,2.89,2.66,2.44,3.57,3.72,2.24,3.42	
		Wall	6061-T6	0.080"	No				12 craters w/ dimples, ~ 0.19" defl., dam area 3.75 x 4.5"
1436	0.187" AI-1100	Shield #1	6061-T6	0.012"	Yes	0.33x0.32,0.28x0.23"			
	0 deg. target angle	Shield #2	6061-T6	0.040"	Yes	0.85" x 1.05"	2	0.17,0.52,0.14	Fine spray, 2 holes, 2nd hole 0.05" dia.
		Wall	6061-T6	0.040"	Yes		5	0.59,0.52,0.41,0.38,0.37	Det. spall, many craters with dimples, fine spray, 3 pin holes
1437	0.187" AI-1100	Shield #1	6061-T6	0.012"	Yes	0.32" x 0.25"			Numerous pin holes
	0 deg. target angle	Stuffing	MLJ Blanket		Yes	See photo			
		Shield #2	6061-T6	0.040"	Yes		6	0.57,0.94,1.18,1.22,0.5,0.4	
		Wall	6061-T6	0.040"	Yes	Largest .12x.09"			Numerous small holes and craters
1438	0.187" AI-1100	Shield #1	6061-T6	0.012"	Yes	Largest .325 x .27"			
	0 deg. target angle	Stuffing	MLJ Blanket		Yes	See photo			
		Shield #2	6061-T6	0.040"	Yes		7	1.46,0.36,1.23,1.85,0.71	
		Wall	6061-T6	0.040"					Missing
1439	0.187" AI-1100	Shield #1	6061-T6	0.012"	Yes	0.35" x 0.31"			Numerous pin holes
		Stuffing	MLJ Blanket		Yes	See photo			
		Shield #2	6061-T6	0.040"	Yes		8	.90,.73,.23,.75,.75,.78,.9,.99	
		Wall	6061-T6	0.040"	Yes	0.125" dia.			3 meas holes .125", 1 x .06", .063x.074", pin holes, fine spray
1442	0.187" AI-1100	Shield #1		0.012"	Yes	0.31" x 0.22"			Several pin holes around projectile entrance
1443	0.187" AI-1100	Shield #1		0.012"	Yes	0.31" dia.			Small hole below and to the right 0.04", numerous pin holes
1444	0.187" AI-1100	Shield #1	6061-T6 Al	0.012"	Yes	0.295" dia.			Shield severely bent, shield cracked on bottom right side
1446	0.187" AI-1100	Shield #1	6061-T6 Al	0.012"	Yes	0.270" dia.			Shield severely bent, numerous pin holes
1450	0.5" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.720" dia.			Detached spall
	0 deg target angle	Shield #2	6061-T6 Al	0.050"	Yes	4.43" max dia.			Wagon wheel, many craters, & dimples
		Wall	2219-T87 Al	0.125"	Yes	0.811" x 0.708"	4	4.34", 5.19", 4.29", 3.25"	Numerous craters
1451	0.5" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	1.163" x 0.794"	0		Elliptical hole
	45 deg target angle	AI Mesh			Yes	See photo	0		
		Nextel 62		6 layers	Yes	See photo	0		
		Kevlar 710		6 layers	Yes	See photo	0		
		MLJ Blanket			Yes	See photo	0		
		Wall	2219-T87 Al	0.125"	Yes	0.661"	3	2.80", 1.93", 2.16"	Numerous craters, no dimples
1452	0.5" AI-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.168" x 1.040"	0		Several debris holes and craters
	45 deg target angle	AI Mesh			Yes	See photo	0		
		Nextel 62		6 layers	Yes	See photo	0		
		Kevlar 710		6 layers	Yes	See photo	0		

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
		MLJ Blanket		6 layers	Yes	See photo	0		
		Wall	2219-T87 Al	0.125"	Yes	0.25"	3	0.81", 2.12", 1.41"	Elliptical damage area 6.042"x4.670"
1453	0.5" Al-1100	Shield	6061 T6 Al	0.063"	Yes	1.114" x 0.825"	0		Debris holes, 2 attached spalls, 4 dimples
	45 deg target angle	Al Mesh				See photo	0		
		Nextel 62		6 layers		See photo	0		
		Kevlar 710		6 layers		See photo	0		
		MLJ Blanket		6 layers		See photo	0		
		Wall	2219-T87 Al	0.190"	No		0		6 lg. craters, ~ deflection of wall 0.821"
1454	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.101" x 0.835"	0		Debris holes and craters, 2 detached spalls
	45 deg target angle	Al Mesh				See photo	0		
		Nextel 62		6 layers		See photo	0		
		Kevlar 710		6 layers		See photo	0		
		MLJ Blanket		6 layers		See photo	0		
		Wall	2219-T87 Al	0.190"	No		0		4 lg. craters, many pits, dam. area 6.1"x4.64", wall defl. ~.362"
1455	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	0.773" max. dia.	0		1 debris hole
	0 deg target angle	B2+ Stuffing			Yes	See photo	0		
		MLJ			Yes	See photo	0		
		Wall	2219-T87 Al	0.190"	Yes	0.880"	5	3.43, 1.53, 3.15, 2.05, 0.73	Damage area 7.176"
		Witness #1			Yes	3.214"	0		Maximum length from edge to edge
		Witness #2			Yes	3.407"	0		Maximum length from edge to edge
		Witness #3			Yes	3.318"	0		Maximum length from edge to edge
1456	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.143" x 0.840"	0		Plated bent toward projectile
	45 deg target angle	Kevlar		26 layers	Yes	See photo	0		
		MLJ			Yes	See photo	0		
		Wall	2219-T87 Al	0.190"	Yes	0.727" x 0.365"	0		Many pits, no dimples
1457	Bad Shot						0		
1458	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.126" x 0.836"	0		
	45 deg target angle	AF26 Nextel		3 layers	Yes	See photo	0		
		Kevlar 120		11 layers	Yes	See photo	0		
		MLJ			Yes	See photo	0		
		Wall	2219-T87 Al	0.190"	Yes	0.035"	0		Fine spray, damage area 5.684"x 3.343
1459	Bad Shot						0		
1466	0.313" Al-1100	Shield #1	6061 T6 Al	0.032"	Yes	0.750" x 0.522"	0		Fine spray
	45 deg target angle	Nextel		3 layers	Yes	See photo	0		
		Kevlar		3 layers	Yes	See photo	0		
		MLJ		10 layers	Yes	See photo	0		
		Wall	2219-T87 Al	0.100"	Yes	0.836" x 0.264"	4	1.71", 1.74", 1.96", 1.34"	Length of petal crack
		Witness #1			No		0		Numerous large craters
		Witness #2			No		0		No apparent damage

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
1467	0.375" Al-1100	Shield #1		0.040"	Yes	0.869" x 0.593"	0		Shield bent outward
	45 deg target angle	Al Mesh			Yes	See photo	0		
		Nextel		2 layers	Yes	See photo	0		
		Kevlar		7 layers	Yes	See photo	0		
		MLI		15 layers	Yes	See photo	0		
		Wall		0.125"	Yes	0.552" x 0.294"	4	1.82", 1.92", 1.59", 2.08"	Length of petal crack
		Witness #1			No		0		Lg. plate defl., 1 detached spall, craters
1468	Bad Shot						0		
1469	0.5" Al-1100	Shield #1	2024 Al	0.025"	Yes		0		
	75 deg target angle	Nextel		2 layers	Yes	See photo	0		
		Kevlar		1 layers	Yes	See photo	0		
		MLI		11 layers	Yes	See photo	0		
		Wall	6061-T6	0.063"	Yes	1.716"	5	2.07, 1.55, 0.91, 1.52, 2.17	Length of petal crack
		Witness #1			Yes		0		Damage area 3.05" dia.
		Witness #2			Yes	.188, .16, .52 x .26	0		3 holes & 3 craters
1470	0.5" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.81" x 1.10"			
	45 deg target angle	Stuffing			Yes	See photo			
		Wall	2219-T87 Al	0.190"	No				2 dimples on rear, 10 craters w/o dimp., dam area 4.25 x 4.5"
1476	0.313" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.54 x 0.79"			
	45 deg target angle	Nextel		2 layers	Yes	See photo			
		Kevlar		7 layers	Yes	See photo			
		MLI		15 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	No				Crack 0.07" long, fine spray, 2 dimples, dam area 2.0 x 2.75"
		Witness #1	2024 Al	0.020"	No				Attached spall, damage area 0.23" x 0.18"
1477	0.375" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.59" x 0.82"			
	45 deg target angle	Nextel		4 layers	Yes	See photo			
		Kevlar		4 layers	Yes	See photo			
		MLI		15 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	Yes	0.84" x 0.85"	4	1.03, 1.57, 0.65, 1.84"	Damage area 2.875" x 4.0"
		Witness #1	2024 Al	0.020"	Yes				5 pin holes, damage area 2.5" x 3.0"
		Witness #2	2024 Al	0.020"	No				5 craters w/ dimples
1478	0.375" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.80" x 0.58"			9 secondary, plate bent toward proj entrance, dimp on front
	45 deg target angle	Shield #2	6061-T6 Al	0.080"	Yes	2.20" x 1.14"			Numerous craters w/ dimples, dam area 4.5 x 4.375"
		Wall	2219-T87 Al	0.125"	Yes	1.23" x 1.19"			2 smaller holes 0.17 x 0.14" & 0.14" d. dam area 2.88 x 3.38"
		Witness #1	2024 Al	0.020"	Yes	4.45" x 3.16"			8 petals
		Witness #2	2024 Al	0.020"	Yes	3.72" x 2.27"			8 petals
1481	0.313" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.68" x 0.97"			6 secondary holes
	45 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes	2.94" x 3.52"	8	1.18, 1.25, 0.28, 1.1, 1.19, 0.58, 0.47, 0.62	
		MLI		12 layers	Yes	See photo			

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
		Wall	2219-T87 Al	0.100"	Yes	2.66" long			Dimples, craters, fine spray, dam area 3.0" x 4.75"
		Witness #1	2024 Al	0.020"	Yes	Pin hole			Attached spalls, damage area 1.875" x 2.375"
1482	0.313" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	0.67" x 0.84"			2 small secondary holes, fine spray
	45 deg target angle	Nextel		1 layer	Yes	See photo			
		Kevlar		3 layers	Yes	See photo			
		MLI		12 layers	Yes	See photo			
		Wall	2219-T87 Al	0.100"	Yes	Max. 0.6 x 0.48"	5	1.21, 1.19, 1.63, 1.18, 1.77"	Damage area 4.0" x 6.0"
		Witness #1	2024 Al	0.020"	No				4 dimples on rear, damage area 3.375" x 4.5"
1483	0.375" Al-1100	Shield #1	6061-T6 Al	0.080"	?	2.64" x 2.75"			Slight petal effect, petals have holes, craters, & dimples
	45 deg target angle	Shield #2	6061-T6 Al	0.040"	Yes	See photo			
		Blanket	MLI	15 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	Yes	0.98" x 1.59"			1 petal, crack lengths 1.25 & 1.72, fine spray, dam area 5 x 7"
		Witness #1	2024 Al	0.020"	Yes	0.80" x 0.59"			~8 craters w/ dimples dam. area 2.0" x 1.75"
		Witness #2	2024 Al	0.020"	Yes	2.65" x 3.83"			Damage area 4.25" x 5.75"
		Witness #3	2024 Al	0.020"	Yes	Pin holes			9 pin holes, attached spalls, dam area 3.5" x 4.0"
1484	0.375" Al-1100	Shield #1	6061-T6 Al	0.080"	Yes	0.76" x 1.0"			
	45 deg target angle	Nextel		2 layer	Yes	See photo			
		Kevlar		2 layers	Yes	See photo			
		MLI		15 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	Yes	0.94" x 1.40"			3 petals, crack length 0.49, .73, .58, 1.8", dam area 4.25 x 4.75
		Witness #1	2024 Al	0.020"	Yes	Crack 1.51" long			Crack 1.51 x 0.27", 5 pin holes, dam area 4.0" x 4.5"
		Witness #2	2024 Al	0.020"	No				Dent in plate 0.50" long
1485	0.250" Al-1100	Shield #1	6061-T6 Al	0.050"	?				
	0 deg target angle	Wall	2219-T87 Al	0.125"	?				
		Witness #1	2024 Al	0.020"	No				Attached spalls, ~11 dimples, dam area 1.875" x 1.375"
1489	0.250" Al-1100	Shield #1	6061-T6 Al	0.0075"	?				
	0 deg target angle	Wall	2219-T87 Al	0.125"	?				
		Witness #1	2024 Al	0.020"	Yes	0.29" x 0.26"			Numerous craters w/ dimples, damage area 3.25" x 2.875"
		Witness #2	2024 Al	0.020"	No				Small dent 0.25" long, attached spall, dam area 0.38" x 0.50"
1491	0.250" Al-1100	Blanket	Kevlar	1 ply	Yes	See photo			
	0 deg target angle	Blanket	B4C		Yes	See photo			
		Blanket	AL	0.20"	Yes	See photo			
		Blanket	Kevlar	5 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	?				
1493	0.250" Al-1100	Shield #1	2024 Al	0.025"	Yes	0.37" x 0.56"			0.08" x 0.11" secondary holes, and 2 pin holes
	45 deg target angle	Blanket	Mesh		Yes	See photo			
		Blanket	Nextel	2 layers	Yes	See photo			
		Blanket	Kevlar	4 layers	Yes	See photo			
		Blanket	MLI	9 layers	Yes	See photo			

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
		Wall	6061-T6	0.080"	Yes	Max. 1.5" x 1.3"	5	1.07, 0.86, 1.07, 0.43, 1.17"	Damage area (max dim) 2.25" x 2.25"
		Witness #1	2024 Al	0.020"	Yes	2 pin holes			Damage area 3.25" diameter
1494	0.375" Al-1100	Shield #1	6061-T6 AL	0.040"	Yes	0.60" x 0.88"			
	45 deg target angle	Blanket	Mesh		Yes	See photo			
		Blanket	Nextel	4 layers	Yes	See photo			
		Blanket	Kevlar	4 layers	Yes	See photo			
		Blanket	MLI	15 layers	Yes	See photo			
		Wall	2219-T87 Al	0.125"	Yes	Max. 0.7" x 0.4"	4	0.88", 0.31", 0.96", 0.75"	Damage area 3.625" x 4.5"
		Witness #1	2024 Al	0.020"	Yes	Lrg 0.32" x 29"			3 holes, damage area 3.75 x 4.0"
		Witness #2	2024 Al	0.020"	No				2 craters w/ dimples, damage area 0.41" x 0.14"
1495	0.375" Al-1100	Shield #1	2024 Al	0.040"	Yes	0.53" x 0.76"			9 secondary holes
	45 deg target angle	Blanket	Mesh		Yes	See photo			
		Blanket	Nextel	2 layers	Yes	See photo			
		Blanket	Kevlar	4 layers	Yes	See photo			
		Blanket	MLI	9 layers	Yes	See photo			
		Wall	6061-T6 Al	0.080"	Yes	Max 1.58 x 1.41"	5	0.38, 0.47, 0.2, 0.42, 0.15	2 small holes, craters dimples, fine spray dam area 5.75 x 8.5"
		Witness #1	2024 Al	0.020"	Yes	Max. 2.71 x 2.3"			Attached spall around hole, damage area 3.375" x 3.5"
1496	0.313" Al-1100	Shield #1	2024 Al	0.040"	Yes	0.46" x 0.51"			
	25 deg target angle	Blanket	Al Mesh		?				
		Blanket	Nextel	2 layers	?				
		Blanket	Kevlar	4 layers	?				
		Blanket	MLI	9 layers	?				
		Wall	6061-T6 Al	0.080"	Yes	Max 3.25 x 3.48"	8	2.1, 72, 1.33, 1.7, 1.83, 1.94, 1.59, 1.84	
		Witness #1	2024 Al	0.020"	Yes	Max 4.44 x 4.6"	8		Damage area 4.75 x 5.75"
		Witness #2	2024 Al	0.020"	Yes	Max 2.5" x 0.52"			Attached spalls, damage area 4.75 x 5.5"
1498	0.250" Al-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.58" x 0.60"			
1502	0.5" Al-1100	Shield #1	6061-T6 Al	0.063"	Yes	1.150" x 0.837"	0		Severely bent outward, craters, detached spall
	45 deg target angle	MLI		20 layers	Yes	See photo	0		
		Nextel		3 layers	Yes	See photo	0		
		Kevlar		6 layers	Yes	See photo	0		
		Graphite Ep.		Sheet	Yes	See photo	0		
		Wall	2219-T87 Al	0.188"	Yes	0.137"	4	0.59", 0.52", 0.88", 0.34"	Fine spray, dam. area 4.69" x 6.0"
1503	0.5" Al-1100	Shield #1	6061 T6 Al	0.063"	Yes	1.118" x 0.822"	0		
	45 deg target angle	MLI			Yes	See photo	0		
		AF-62 Nextel		5 layers	Yes	See photo	0		
		Graphite Ep.		Sheet	Yes	See photo	0		
		Wall	2219-T87 Al	0.188"	Yes	0.362" x 0.223"	0		Fine spray
		Witness #1			Yes	0.61" x 0.46" & 0.39" x 0.19"	0		Damage area 1.43" x 1.67"

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
304 Stainless Steel Projectile									
Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
1505	0.25" 304 S.S.	Shield #1			Yes	0.327"	0		
		Wall #1			Yes	0.40"	0		Minor detached spalls
		Wall #2			Yes	0.42"	0		Fine spray
		Wall #3			Yes	0.45" x 0.35"	0		Damage area 1.1" x 1.3"
1506	0.25" 304 S.S.	Shield #1			Yes	0.351"	0		
		Wall #1			Yes	0.413" x 0.387"	0		Fine spray
		Wall #2			Yes	0.470" x 0.575"	0		Fine spray
		Wall #3			Yes	0.400" x 0.489"	0		Fine spray

Aluminum Projectile

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
1507	0.25" Al-1100	Shield #1	2219 T87 Al	0.125"	Yes	0.685"	0		
		Shield #2	6061-T6 Al	0.032"	Yes		8	Max=1.62", Min=1.23	Numerous small holes, fine spray
		Shield #3	2024 Al	0.020"	Yes		7	Max=2.2", Min=1.68"	
		Shield #4	2024 Al	0.020"	Yes		5	2.96", 2.25", 1.7", 2.28", 3"	
		Wall	6061-T6 Al	0.080"	No		0		Slight indentation at impact
1509	0.313" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.722" x 0.527"	0		Fine spray
	45 deg target angle	MLI					0		
		Nextel		2 layers			0		
		Kevlar		2 layers			0		
		Wall	2219 T87 Al	0.125"	No		0		Craters, damage area 5.17" x 3.15"
1524	0.25" Al-1100	Shield #1	2219 T87 Al	0.125"	Yes	0.69"	0		
		Shield #2	6061-T6 Al	0.032"	Yes		10	Max=2.13", Min=1.5"	Numerous small holes
		Shield #3	6061-T6 Al	0.012"	Yes		10	Max=1.88", Min=0.743"	Numerous craters, small holes
		Shield #4	6061-T6 Al	0.012"	Yes		7	Max=2.43", Min=1.67"	
		Wall	6061-T6 Al	0.080"	No		0		Slight indent, fine spray, dam area 2.19" dia
1528	0.313" Al-1100	Shield #1	6061-T6 Al	0.040"	Yes	0.72" x 0.52"	0		
	45 deg target angle	MLI		15 layers	Yes	See photo	0		
		Nextel		2 layers	Yes	See photo	0		
		Kevlar		2 layers	Yes	See photo	0		
		Wall	2219 T87 Al	0.125"	Yes	0.53"	1	0.38", 0.47"	Damage area 2.5"
		Witness #1			Yes	0.03"	0		21 craters
1529	0.187" Al-110	Shield #1	2219 T87 Al	0.125"	Yes	.579"	0		
	0 deg target angle	Shield #2	6061-T6 Al	0.032"	Yes		6	.92", 1.13", 1.17", 1.18", .82", 1.13"	
		MLI		25 layers			0		
		Shield #3	6061-T6 Al	0.012"	Yes	Max .16, Min .02	0		8 holes total, damage area 2.25" dia.

Shot	2nd Projectile	Description	Material	Thickness	Pen.	Hole Diameter	Petal	Length of Crack Petals	Damage Description
		MLI		15 layers			0		
		Shield #4	6061-T6 Al	0.012"	No		0		2 craters
		Wall	6061-T6 Al	0.080"	No		0		No visible damage
1531	0.313" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.61" Dia			Numerous small holes
	0 deg target angle	Wall	2219 T87 Al	0.125"	Yes				
		Witness #1	2024 Al	0.020"	Yes	2.75"x 1.0"			
		Witness #2	2024 Al	0.020"	Yes		3	2, 25", 18" & 34, 38, 35"	3 holes, 2 w/ 3 petals & 1 w/ debris in hole, 3rd small
		Witness #3	2024 Al	0.020"	No				1 large crater 0.22" x 0.15"
1545	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.65"x 0.91"			Plate bulged toward proj. several small holes & craters
	45 deg target angle	MLI		15 layers	Yes	See photo			
		Nextel		4 layers	Yes	See photo			
		Kevlar		4 layers	Yes	See photo			
		Wall	2219 T87 Al	0.125"	Yes	0.50"x 0.066"			1 large horizontal crack 2.9", several large craters
		Witness #1	2024 Al	0.020"	No				Damage area 1.22"x 0.64", 3 dimples on rear
1546	0.375" AI-1100	Shield #1	6061-T6 Al	0.032"	Yes	.61x1.05, 28x.41"			Shield severely bulged toward the projectile entrance
	60 deg target angle	MLI		10 layers	Yes	See photo			
		Nextel		3 layers	Yes	See photo			
		Kevlar		3 layers	Yes	See photo			
		Wall	2219 T87 Al	0.093"	Yes				Vert. crack 1.4", wall bulged toward proj. many craters, no hole
		Witness #1	2024 Al	0.020"	No				No apparent damage
1548	0.375" AI-1100	Shield #1	6061-T6 Al	0.050"	Yes	0.65"x 0.89"			Shield bulged toward proj. entrance
	60 deg target angle	Shield #2	2219 T87 Al	0.096"	Yes	Max. 2.54x1.47"			Large hole w/ fingers, craters, 3 cracks .37, .18, .29, small hole
		Wall	2219 T87 Al	0.125"	Yes		4	2.13", 1.72", 1.67", 1.73"	2 holes, small hole 0.16" to left of lg. hole
		Witness #1	2024 Al	0.020"	Yes	0.6"x 0.63"x 0.64"			Numerous small holes, largest hole triangular shaped
		Witness #2	2024 Al	0.020"	Yes		3	0.16", 0.38", 0.55"	4 holes, 1 crack joins 2 holes

CONCLUSIONS

A number of physical parameters from high velocity impacts on space station walls and bumpers were measured and recorded. The amount of impact damage observed includes a large range of combinations.

